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APOLLO LOGISTICS SUPPORT SYSTEMS MOLAB STUDIES

CREW STATION CONCEPTUAL STUDY OF

LOCOMOTION PANEL DISPLAY PARAMETERS AND

DIGIT CONTROL FOR A LUNAR MOBILE LABORATORY

Prepared under Contract No. NAS8-5307 by

Alan D. McNair
Chief, Bio-Mechanics Section

HAYES INTERNATIONAL CORPORATION
Apollo Logistics Support Group

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1.0 PLAN OF APPROACH

1.1 GENERAL

In order to establish ALSS/MOLAB crew-station design criteria upon which preliminary designs can be based, a parametric analysis must be performed. This task is a study concerned with the locomotion panel and controls, panel display requirements, crew tasks, knobs, switches, dials, digit control criteria, panel and control locations, etc.

1.2 SCOPE

The parametric analysis of the locomotion controls and displays will include the following: a functional description of the MOLAB locomotion mechanisms and techniques, an analysis of locomotion parameters to determine visual displays and hand and foot control requirements, and determination of the design criteria for visual displays and controls. Also, the human engineering requirements will be investigated to determine the type of controls, such as side-stick, foot, wheel, or a combination of these, which will be utilized. A study of the location, size, shape, type, and dimensions of switches, buttons, knobs, etc., on these controls will be conducted.

The anthropometric and human tolerances for flying personnel (astronauts) will be used as ground rules throughout this study. All information released by the ALSS Program Manager will be utilized as guidelines and restraints for this study.

2.0 MOLAB WHEEL DRIVE MECHANISMS AND TECHNIQUES

2.1 DESCRIPTION OF LOCOMOTION MECHANISM[20, 17]

The following description of a MOLAB drive mechanism is conceptual in nature and is the result of preliminary studies of a MOLAB.

2.1.1 WHEELS

The MOLAB vehicle has four "metalastic" wheels, 60 inches in diameter and 12 to 14 inches wide, providing an elongated footprint of approximately 400 inches^2 per wheel with a static deflection of 5 inches.

2.1.2 POWER SUPPLY AND DRIVE UNIT

The wheels are powered individually by an electric motor located inside the hub of each wheel. Each motor is a 28 volt DC motor and produces one HP at 3600 RPM with a resulting torque of 17 in-lbs to a 5/8 inch shaft. The torque is transmitted to the wheel through a harmonic drive unit. The harmonic drive unit and the wheel are connected electro-mechanically. This allows an electric disengagement to provide a free-wheeling mode for each wheel. The harmonic drive unit, with a ratio of 1:50 and an input of 3600 RPM, allows vehicle speeds to 10 MPH on a hard level surface ($K\phi = 6$, $N = 1.25$).

2.1.3 GENERATORS

The electric drive motors function as generators when operated for dynamic braking.

2.1.4 RADIATOR

Each wheel has a radiator to dissipate the heat generated at the electric motors during the driving and braking mode of operation.

2.1.5 BRAKES

Mechanical friction brakes and dynamic braking by the electric wheel drive motors are both under consideration. The dynamic braking method has an advantage in that the electric wheel drive motors function as generators while being used for dynamic braking.

2.1.6 STEERING

Steering control is accomplished by the use of a relatively constant speed, high starting torque motor located at each wheel. During turn correction, the steering motor drives the wheels to a null position; wheel position is indicated on the control panel.

The steering mechanism proposed for the MOLAB will be a geometric type which will enable both two wheel and four wheel steering with a minimum turn radius of approximately 21.5 feet. Scuff steering is under study at the present time.

2.2 DESCRIPTION OF DRIVE TECHNIQUES (MANUAL ONLY)

2.2.1 FORWARD, REVERSE, AND VELOCITY CONTROL

This concept of locomotion control envisions that the selection of vehicle direction (forward, reverse, left, or right), the control of acceleration and constant velocity, and the normal braking, is controlled by a hand-operated multifunctional locomotion control lever. See Figure 1.

Assuming that the first step of starting the MOLAB --- activating the fuel cells and checking out the electrical system instruments --- has been accomplished, the desired direction of vehicle movement (forward or reverse) is selected by movement of the locomotion control lever into the appropriate detent. The lever may be positioned at any location in the detent, from zero to full power, in a forward (10 MPH, maximum) or reverse (2 1/2 MPH maximum) direction. The detent is designed so that the power may be changed in definite increments of 10 percent (10 positions) in forward and 33 1/3 percent (3 positions) in reverse, if necessary. In the event that wheel revolutions become unequal, an individual vernier-type digital control is provided on the control panel to allow an adjustment of power to the unsynchronized wheel.

2.2.2 DRIVE MODE SELECTION

The operator has a choice of selecting a two-wheel drive, a four-wheel drive, or a completely free-wheeling mode. Wheel-drive selector switches are provided on the control panel. If actuated, the switches cut off power to the wheel drive motors and cause a disengagement between the drive train and the wheel. Therefore, if a malfunction occurs in a drive motor or a drive train, it may be isolated from the locomotion subsystem without causing a drag force on the wheel.

2.2.3 BRAKING[17]

Dynamic braking is controlled by the retardation of the locomotion control lever. By returning the locomotion lever from a "power on" to a zero (neutral) position, maximum normal dynamic braking is achieved. Emergency braking is achieved by the actuation of the emergency stop button or switch, which is located on or in close proximity to the locomotion lever.

2.2.4 STEERING (ACKERMANN --- TWO OR FOUR WHEEL)[21]

The direction of steering is controlled by tilting the upper part of the locomotion control lever in the desired direction of turn. After the desired angle of turn has been reached, the lever is allowed to return to a vertical position. To turn the wheels back to a straight-ahead position, the lever is tilted in the opposite direction and the wheels stop automatically in the straight-ahead position.

An instrument is provided on the locomotion control panel to display to the operator the number of degrees that each wheel has turned. If, due to a restriction or malfunction, a wheel has not turned to the proper angle, a vernier-type adjustment knob on the control panel provides a means for the operator to individually control the steering motors and have a realignment capability from within.

2.2.5 STEERING REDUNDANCY

If a malfunction of the steering subsystem (motor failure, etc.) occurs, the vehicle still can be turned by the scuff method. Individual-power on or off switches for each wheel-drive motor are provided on the control panel. By cutting off the power to the wheels on the inside of the desired turn, and controlling the power to the outside wheels with the locomotion control lever, turns may be negotiated.

3.0 ANALYZATION OF LOCOMOTION PARAMETERS FOR VISUAL DISPLAYS AND HAND AND FOOT CONTROL

3.1 STEERING

FUNCTIONAL REQUIREMENT	CONTROLLER	OPERATOR HAND OR FOOT	VISUAL DISPLAY	QUANTITY
1. (a) Two Wheel Ackermann Steer. or (b) Four Wheel Ackermann Steer.	(a) Selector Switch (b) Selector Switch	(a) Hand (b) Hand	(a) Label 2 Position, Off-Front (b) Label 2 Position, Off-Rear	(a) 1 (b) 1
2. Emergency Scuff Steering	Utilize Free-Wheel Switches	Hand	--	--
3. Directional Control Mechanism	Wheel, Stick, Knob	Hand	Composite Display to Indicate Angle Turned (Desired Compared to Actual) for Each Wheel	1
4. Wheel Realignment	Rotary Switch	Hand		2
5. Wheel Realignment Selector	Power Switch (Redundant)	Hand	Label 2 Position, Front-Rear	1
6. Steering Motor Failure Warning Light (Integral)			Flashing Light	4

3.2 DRIVE AND BRAKING

FUNCTIONAL REQUIREMENT	CONTROLLER	OPERATOR HAND OR FOOT	VISUAL DISPLAY	QUANTITY
1. Speed Control Mechanism and	Stick	Hand	Labeled and Detented Power Selector	1
2. Direction Selector (Forward and Reverse)	Stick	Hand	Label and Detents for Direction Selection	1
3. Emergency Stop	Pushbutton	Hand	Label	1
4. Wheel or Drive Motor Conditions	----	---	Mechanical Indicators (Dials, Bars ...)	4
(a) RPM			Qualitative Readouts for Each	4
(b) Temp.				4
(c) Amperage				4
(d) Warning System (Integral with Above Parameters)			Flashing Light	4
5. Power-Off Switch for Individual Drive Motors in Event of Failure or Overtemp. Condition	Switch	Hand	Label 2 Position, Drive - Freewheel	4
6. Switch to Allow Selection of: (a) Front Wheel Drive (b) Rear Wheel Drive (c) Both	Switch	Hand	Label 2 Position, Front-Both-Rear Drive Front-Freewheel Rear-Freewheel	2

3.3 TIME AND DISTANCE MEASUREMENT

FUNCTIONAL REQUIREMENTS	CONTROLLER	OPERATOR HAND OR FOOT	VISUAL DISPLAY	QUANTITY
1. Time Indication (a) 24 Hour Clock	(a) Calibration Knob	(a) Hand	(a) Digital Indicator	(a) 1
(b) Total Elapsed Time	(b) ----	(b) ----	(b) Digital Indicator	(b) 1
2. Distance Traveled Indicator			Digital Indicator	1
3. Range Warning System-Integral with Distance Measuring Equipment			Flashing Light	1

4.0 FUNCTIONAL DESCRIPTION OF DISPLAYS AND CONTROLS

4.1 MULTI-FUNCTIONAL LOCOMOTION CONTROL LEVER

A method of control is required for the following locomotion parameters:

a) Power

b) Brakes

c) Fore-aft direction

d) Steering

The above parameters are controlled electrically rather than mechanically; consequently, the forces required to actuate the controller may be very small. By the use of a multi-functional control lever, the control of the locomotion parameters is determined by the position of a single controller rather than the coordinated positions of two (or more) separate controllers which must be coordinated to varying degrees. This allows the operator full control of the parameters with a minimum amount of physical effort and actuation time. Furthermore, the sense of the system is completely natural and instinctive as well as compatible with aircraft-type controls.[8, 19]

The method of operation is described in Section 2.2.

4.2 WHEEL REVOLUTION INDICATOR

Each wheel-drive motor requires one RPM visual display to reflect or assist in the detection of unsynchronized wheel speed due to the following situations:

a) A loss of traction

b) Unequal power distribution to the wheel-drive motors

c) Mechanical or electrical malfunction

d) Excessive temperature

If a RPM display should indicate an abnormal reading, a comparison with the amperage indicator and with the temperature indicator for the same wheel-drive motor will provide data which will assist the operator in evaluating the malfunction.

4.3 WHEEL-DRIVE MOTOR TEMPERATURE INDICATOR

Each wheel-drive motor requires one temperature visual display to reflect or assist in the detection of the following situations:

a) High temperature caused by over-exposure to solar radiation

b) Bearing or other mechanical failure

c) Short circuit

d) Wheel restraint due to surface conditions

Should an abnormal indication caused by one of the above listed situations occur, the temperature display indicator compared primarily with the amperage indication and secondarily with the RPM indication for the same wheel-drive motor will provide data which will assist the operator in evaluating the malfunction.

4.4 WHEEL DRIVE MOTOR AMPERAGE INDICATOR

Each wheel-drive motor requires one amperage visual display to reflect or assist in the detection of the following situations:

a) Equal or unequal power distribution to the wheel-drive motors

b) Short circuit

c) Mechanical malfunction (increased friction)

d) Excessive temperature

e) Inoperable drive motor

Unequal power distribution is a prime concern in the conversion of power. Unequal power distribution to the drive motors would waste electrical energy through unbalanced driving and also would cause wheel scuffing.

If an amperage display should indicate an abnormal reading, immediate comparison of the RPM and the temperature indications for the same wheel-drive motors will provide data which will assist the operator in evaluating the malfunction.

4.5 DRIVE MOTOR WARNING SYSTEM

A drive motor warning system visual display is required in the event that the maximum limitation of the following wheel-drive motor parameters are exceeded:

a) RPM

b) Amperage

c) Temperature

The warning system visual display should provide one indicator, integral with the above parameters, for each wheel. The actuation of a warning device would immediately alert the operator, indicating which drive motor had a limitation excess. The visual displays for the above parameters are coded to indicate safe and unsafe operating ranges; therefore, one or more visual displays indicating "unsafe" will be immediately noticed by the operator, giving indication of the nature of the malfunction.

4.6 INDIVIDUAL WHEEL POWER CONTROL SWITCH

A control switch for each wheel is needed in order to simultaneously perform the following functions:

a) Stop the electrical energy flow to the drive motor

b) Cause an electro-mechanical disengagement between the wheel and the drive train

This control switch would be required to break the electrical circuit to the drive motor and electro-mechanical clutch if the following situations occurred:

a) High temperature condition at wheel-drive motor

b) Mechanical failure of wheel-drive component

c) Electrical failure in the wheel-drive circuit

d) Failure of Ackermann steering system -- the control switch would facilitate scuff steering

These manual override control switches would provide a redundancy, assuming the electrical system has circuit breakers for use in the event of excessive amperage at a particular wheel-drive motor. Should the operator be alerted by the locomotion control panel visual displays that a malfunction has occurred at a wheel-drive motor location, and if the circuit breaker should fail, the switches would provide a redundant control. Also, they would provide a redundancy in the steering subsystem by allowing scuff steering in the event of a failure in the normal system.

4.7 VERNIER POWER ADJUSTMENT

Wheel RPM equalization is important for maximum power utilization in normal, straight-line locomotion. The factors which will cause variance in the individual wheel RPM are:

a) Coefficient of friction between wheel and lunar surface

b) Friction inherent in the drive mechanism

c) Temperature of the drive motor

d) Unequal power distribution

Each wheel-drive motor requires one hand-operated rotary type switch to provide a means of making a small range of power increases or decreases independent of the primary power control devices. In the event that wheel speed becomes unsynchronized and an adjustment is necessary, it would normally be accomplished while the MOLAB is in motion over a relatively smooth, compact lunar surface.

4.8 DRIVE MODE SELECTOR

Two hand-operated selector switches are required to provide the operator a choice of having drive power at:

a) Two wheels

b) Four wheels

c) No wheels (complete free-wheeling)

These switches serve essentially the same function as the individual wheel power control switches; however, the operator would use them for entirely different functions. The two front wheels are actuated by one switch; the two rear wheels are actuated by a second switch. Therefore, two switches are provided on the locomotion control panel so that the operator may choose two-wheel drive, front or rear; four wheel drive; or complete free-wheeling (coasting requires no power consumption).

The two groups of controls, the individual wheel power controllers and the drive mode selectors, would provide some redundant control.

4.9 DISTANCE TRAVELED INDICATOR

A distance-measuring visual display is required to serve the following functions:

a) For use in the calculation of average speeds

b) For use as a safety device

c) For use in association with scientific data recording

The first and second functions listed above are concerned with locomotion. The MOLAB has a specific range of travel which is limited by the amount of electrical power available for locomotion, breathing oxygen, and other factors. Knowledge of distance traveled as a function of time is essential to navigation and safety.

4.10 RANGE WARNING SYSTEM

A range warning system visual display is required as a safety device to alert the operator to the fact that a specific, pre-set distance-traveled limitation has been reached. This warning system would be integral with the distance measuring equipment of the locomotion system.

4.11 TIME INDICATOR

A visual display of total elapsed time and also a basic clock is required for the following reasons:

a) Schedule maintenance

b) Provide data for time and distance calculations

c) Safety

e) Other reasons unrelated to locomotion

As applicable to the locomotion system, time indicators will be used in support of other indicators for rate calculations such as flow rate, distance traveled per unit of time, etc.

4.12 EMERGENCY STOP CONTROL

An emergency stop control is required to actuate the emergency braking system which is separate from the normal braking system. It will have only two positions, off and full stop, and will be used for the following reasons:

a) To provide stopping in a shorter distance than is possible with the normal braking system

b) Failure of normal braking system

c) To hold the vehicle at a full stop position for prolonged periods of time

4.13 STEERING ANGLE INDICATOR

A steering angle visual display, to indicate wheel alignment or misalignment, is required for each wheel. Wheel misalignment could occur for the following reasons:

a) Steering motor malfunction

b) One wheel restrained by the lunar surface while the other wheels turn

c) Striking an obstacle during the driving mode

Driving or turning with a wheel out of alignment, depending on the degree of misalignment, could prevent mobility completely or at best cause an uneconomical use of power. Realignment could be made from the locomotion control panel by using the alignment control.

4.14 WHEEL ALIGNMENT CONTROL

A wheel alignment controller is required to provide the operator with a wheel realignment capability from within. This controller allows the operator to actuate each steering motor individually. By visually monitoring the steering angle indicator and actuating this control, wheel realignment can be achieved.

4.15 STEERING MOTOR WARNING SYSTEM

A steering motor warning system visual display is required to alert the operator to the following:

a) Steering motor overloading

b) Steering motor circuit failure

One warning light for each wheel is utilized. In the event that the operator is alerted by a warning light during steering motor actuation, the locomotion control lever is returned to vertical (steering power off) position. Indicatons provided by the steering angle display and the warning lights during conditions of "power on" and "power off" to the steering motors will enable the operator to evaluate the malfunction.

5.0 DESIGN CRITERIA FOR LOCOMOTION VISUAL DISPLAYS AND HAND CONTROLS

5.1 VISUAL DISPLAYS

5.1.1 GENERAL[1]

The following general criteria shall apply to all visual displays:

a) It can be read quickly in the manner desired (i.e., quantitative, qualitative, and check).

b) It can be read accurately as demanded by the operator's needs, and preferably no more accurately.

c) It is free of features which produce ambiguity or invite gross reading errors.

d) The information is provided in the most immediately meaningful form, not requiring mental translation into other units.

e) Changes in indication are easy to detect.

f) The indicator is easily identified and distinguished from other instruments.

g) It tells the operator which controls to use in changing its reading.

h) It tells the operator in which direction to operate the controls.

i) The information is current, i.e., lag is minimized.

j) If inoperative, the instrument cannot be read or the operator is properly warned.

5.1.2 WHEEL-DRIVE MOTOR DISPLAYS

The wheel-drive motor visual displays are required to provide qualitative readouts as they will maintain stable values for given operating conditions and would be read comparatively.[2] Readouts will be of special interest when they deviate from desired values. The primary wheel-drive motor visual displays are:

a) Wheel revolution indicators
b) Wheel-drive motor amperage indicator
c) Wheel-drive motor temperature indicator

One display is required for each of the four wheel-drive motors. These displays have the following criteria:

a) Circular type mechanical indicator[2]
b) One revolution indicator[2,19]
c) Fixed scale having a minimum diameter of 1 3/4 inches[2,4] unless specific restrictions are imposed. Diameter may increase, depending upon control panel and operator viewing distances.

d) Viewing distance of 28 inches is optimum[1, 2]

e) Moving pointer which moves clockwise to indicate an increase in magnitude of reading. A straight, simple pointer of 3/32 inches width for scale of 1 3/4 inches diameter shall be used.[5] The tip width shall be the same as the smallest scale division index with the tip angle 20° or less. The pointer shall be the same color as the indices. The pointer shall be as close as possible to the index, but not covering any point.[3, 19]

f) Zero or starting position on the scale to be at the nine o'clock position.[2]

g) Scale graduation dimensions are a function of the illumination level for the indicators and also of the scale range. Scale marks of 1/64 inch width and graduation intervals of 7/64 inch as measured from graduation mark midpoints are under the lowest levels of illumination.[4]

h) Minimum brightness level is 0.01 foot lamberts.[2, 4]

i) Indicators to have a coded dial with a warning window to be exposed during limitation excess.[10, 19]

j) Colors to be used for these indicators are dependent upon the type of interior and night lighting used. The following color coding will generally apply except under conditions where color coding is important under night lighting from a colored light source.[4, 10]

Color	Condition
Red	Danger
Yellow	Caution
Green	Desirable
Blue	Desirable

Under night lighting conditions where display of various operating conditions must be coded, the use of shape coding shall be used.

5.1.3 WARNING SYSTEM DISPLAYS[8]

The warning system shall have lights as indicators. Following are the systems and the number of lights required by each:

a) Drive motor warning system - 4

b) Steering motor warning system - 4

c) Range warning system - 1

The following criteria shall apply to the warning lights: [19]

a) Color - red

b) Intermittent light, rather than steady, at a rate of four flashes per second with equal time for the light and dark intervals

c) Minimum diameter of 1/2 inch

d) Brightness shall be at least as bright as the brightest source on the panel and several times as bright as the background against which they appear.

e) Two brightnesses shall be used: one for daylight and one for night

f) The warning light shall be within 30° of the normal line of sight.

5.1.4. DIGITAL DISPLAYS [7, 15]

The following displays are symbolic-mechanical indicators of the direct reading type:

a) Distance traveled indicator

b) Time indicator

The distance traveled indicator shall display the total miles and tenths of miles traveled.

The time indicator shall display the time of day in hours, minutes, and seconds on a 24 hour clock basis. It shall also indicate the total elapsed time in 24-hour days, hours, and minutes.

The following additional criteria shall apply to these indicators: [6,7,19]

a) The numbers will change by snap action

b) A manually operated rotary knob setting control shall have a ratio of 36° to 45° control knob rotation for one digit counter movement. Clockwise movement shall increase the indication.

c) The illumination and view distance will determine the number size and space. Legibility must be available at minimum normal conditions of illumination.

5.1.5 STEERING ANGLE INDICATOR [21]

This mechanical indicator will display the actual angle that each wheel has turned compared to the angle it should have turned. The scale range is from full left turn (number of degrees) to straight ahead (zero degrees) to full right turn (number of degrees).

During a turn of the vehicle with the Ackermann type steering, the wheel inside the turn has a greater angle than the wheel on the outside of the turn. Therefore, the angle that a wheel turns for any specific vehicle turn radius is a variable, depending upon whether the turn is to the right or to the left.

One concept of an indicator that would display the required value is that of a fixed circular scale type with a moving pointer for each wheel. Two scales, one for a right turn and one for a left turn, which can be read from the same pointer, are provided. The null or zero degree position will be at the twelve o'clock position for the front wheels. For the rear wheels, an identical display would be inverted. (See concept in Figure 2.)

All the criteria of a fixed circular scale with moving pointers applies.

5.2 HAND CONTROLS[12]

The control manipulability, as well as the glove tenacity, snugness, and suppleness of the gloved hand of a 5 to 95 percentile astronaut wearing a pressurized Apollo space suit, are considered in the spacing and design of the hand controls.

Listed below are the hand controls required, their type, the number required, the number of positions, and the general criteria for each.[9]

5.2.1 TOGGLE SWITCHES

The following general criteria applies to toggle type switches:[11,19]

a) Lever tip width or diameter:

Minimum	1/8 inch
Maximum	1 inch

b) Lever-arm length:

Minimum	1/2 inch
Maximum	2 inches

c) Displacement:

Minimum	40 degrees
Maximum	120 degrees

d) Resistance:

Minimum	10 ounces
Maximum	40 ounces

e) Number of positions:

Minimum	2
Maximum	3

Toggle switches should not be spaced any closer than one inch between centers.[11] The physical characteristics of the toggle switches such as length of arm, angle traveled between the two positions, dimensions of arm, surface roughness at tip of arm, and tangential force at arm tip required to operate the switch may be determined after the space allowed for switches on the panel and the control manipulability characteristics of the astronaut's gloved hand are known.

The frequency of inadvertant operation of toggle switches can be minimized by using switches of smaller dimensions and larger resistance to operation as spacing decreases.[11]

5.2.1.1 Individual Wheel Power Control Switches - Criteria

a) One for each wheel (Total of four)

b) Toggle-type switch

c) Two positions each: power on and power off

d) Actuation direction to be vertical[11]

e) "Up" position to be the power on

5.2.1.2 Drive Motor Selector - Criteria

a) Two selectors required

b) Toggle type switch

c) Two positions each: power on and power off

d) Actuation direction to be critical[11]

e) "Up" position to be power on

5.2.1.3 Wheel Alignment Control Selector Switch - Criteria

a) One switch required

b) Toggle type switch

c) Two positions: front and rear

5.2.2 ROTARY SWITCHES [19]

5.2.2.1 Vernier Power Control - Criteria

a) Four shape-coded switches required, one for each wheel

b) Non-incremental control

c) Fixed scale with moving pointer

d) Steps at beginning and end of the range

e) Pointer to be a bar-type knob with a tapered end

f) Width or diameter:

Minimum ----

Maximum 1 inch

g) Depth:

Minimum	1/2 inch
Maximum	3 inches

h) Length:

Minimum	1 inch
Maximum	----

i) Displacement:

Minimum	15 - 30 degrees
Maximum	40 degrees

j) Resistance:

Minimum	12 ounces
Maximum	48 ounces

5.2.2.2 Wheel Alignment Control - Criteria [19]

a) Two-shape-coded switches required, one for each wheel

b) Non-incremental control

c) No scale (scale and pointer are on steering angle indicator)

d) Stops at beginning and end of range

e) Knob type switch

f) Less than one full turn from stop to stop

g) Minimum of 1 1/4 inches between edges

h) Diameter:

Minimum	1/4 inch
Maximum	4 inches

i) Depth :

Minimum	1/2 inch
Maximum	1 inch

j) Resistance :

Minimum	---
Maximum	4 1/2 ounces (knobs up to 1 inch in diameter)
	6 ounces (knobs larger than 1 inch in diameter)

5.2.2.3 Emergency Stop Control - Criteria[13,19]

a) One pushbutton switch required

b) Color coded - red

c) Push-on, push-off

d) Built-in elastic resistor, starting low and building up rapidly with a sudden drop to indicate that control has been actuated

e) Minimized displacement required to activate

f) Top of pushbutton to be concave to fit finger or to have very rough surface

g) Diameter:

Minimum	3/4 inch
Maximum	---

h) Displacement:

Minimum	1/8 inch
Maximum	1 1/2 inches

i) Resistance :

Minimum	10 ounces
Maximum	40 ounces

5.2.2.4 Multi-Functional Locomotion Control Lever - Criteria

The configuration and dimensions of this control are determined in accordance with Section 5.2. See conceptual design, Figure 1. One control lever is required; it is a side-stick type which controls power, braking, steering, and fore and aft direction.[5,8]

5.2.2.4.1 Side Stick, General Criteria [8,19]

a) Side stick designed for right-handed, fore and aft movement

b) Maximum forward power achieved by placing control in full forward position; maximum power in reverse direction achieved by placing control in full aft position

c) Stick is spring-loaded to retain a position

d) Minimum resistance - 2 pounds

Maximum resistance - adjustable

e) Range of movement to be determined according to Section 5.2 and arm rest design

f) Lag in the control system must be kept to the very minimum

5.2.2.4.2 Upper Part of Stick (Steering)

a) Top section of the stick will be pivoted to allow transverse movement

b) Stick is spring-loaded for built-in resistance

c) Maximum angles of left and right movement and maximum torque limited by comfortable operation level of astronaut. (To be determined)

d) Minimum control resistance - a level which will prevent inadvertant actuation.

5.2.2.4.3 Side-Stick Detent [5,18]

a) Incremental power control

Forward - 10 increments

Reverse - 3 increments

b) Detent to allow two parallel vertical planes of movement. The plane closest to the operator to be for the selection of forward direction and speed control. A neutral position will allow plane change so that reverse motion can be selected. Detent will have a "stop" to prevent inadvertant selection of reverse direction. The reverse direction and speed can be selected in the plane fartherest away (outboard) from the operator.

c) The detent positions of forward, neutral, and reverse will be labeled.

d) Each increment of the power range in forward and reverse will be labeled.

6.0 LOCOMOTION CONTROL PANEL

Section 6.1 lists the parameters and appropriate controls and displays for a MOLAB locomotion system. Also, to properly relate the parameter displays and controls with their respective subsystems, the following criteria is established:[22]

a) Relative significance of each parameter: critical, routine, or least critical

b) Relative frequency with which each parameter would be monitored or controlled: high, medium, or low

c) Parameter priorities: primary, secondary, or emergency

6.1 PARAMETER PRIORITIES

Parameter	Significance	Frequency of Operation or Monitor	Priority
Drive and Braking			
Multifunction Control Lever	Critical	High	Primary
Emergency Stop Control	Critical	Low	Emergency
Vernier Power Adjustment	Routine	Medium	Secondary
Individual Wheel Power Control	Least Crit.	Low	Secondary
Drive Mode Selector	Routine	Medium	Secondary
Wheel Revolution Indicator	Critical	High	Primary
Wheel Drive Motor Temperature Indicator	Critical	High	Primary
Wheel Drive Motor Amperage Indicator	Critical	High	Primary
Drive Motor Warning System	Routine	Low	Emergency
Steering			
Steering Angle Indicator	Critical	High	Primary
Steering Motor Warning System	Routine	Low	Emergency
Wheel Alignment Control	Critical	Low	Secondary
Time and Distance Measurement			
Distance Traveled Indicator	Routine	Medium	Secondary
Range Warning System	Least Crit.	Low	Emergency
Time Indicator	Least Crit.	Medium	Secondary

6.2 GENERAL CRITERIA

The anthropometric work-place dimensions and the visual requirements of a 5 to 95 percentile astronaut wearing a pressurized Apollo space suit must be used as constraints during panel layout.

The following criteria applies to general panel layout:[1,16,19]

a) Viewing angle - perpendicular to the face of the visual display.

b) Viewing distance - optimum 28 inches

c) Distance between visual displays to be minimized; horizontal separations to be greater than vertical separation

d) The visual displays of identical parameters are arrayed horzontally

e) All displays and control devices for a wheel drive motor location are arrayed vertically

f) The emergency stop control to be located near the multi-functional control lever to minimize actuation time

g) The multi-functional control lever to be located on the operator's right for right-handed operation

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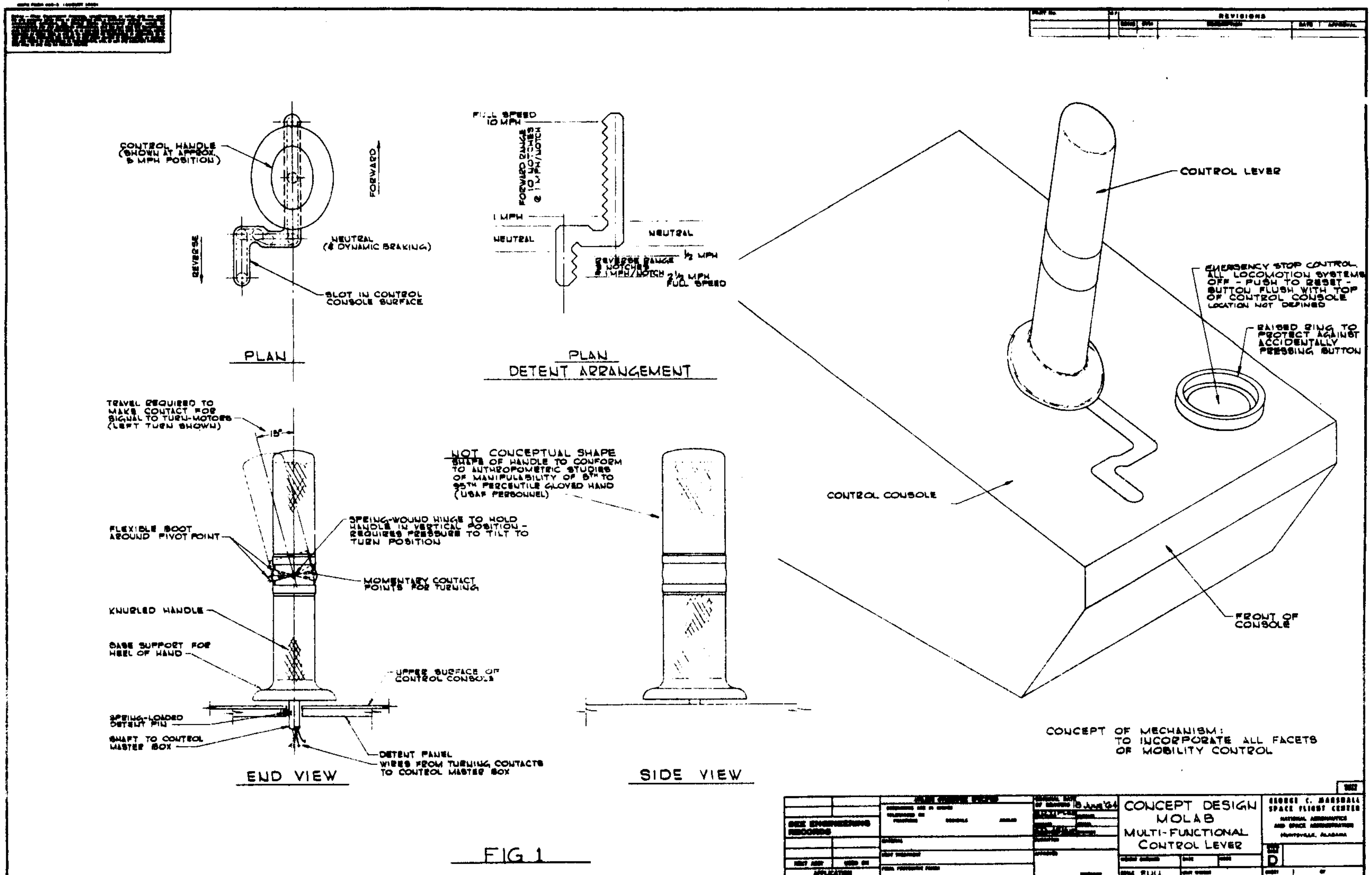
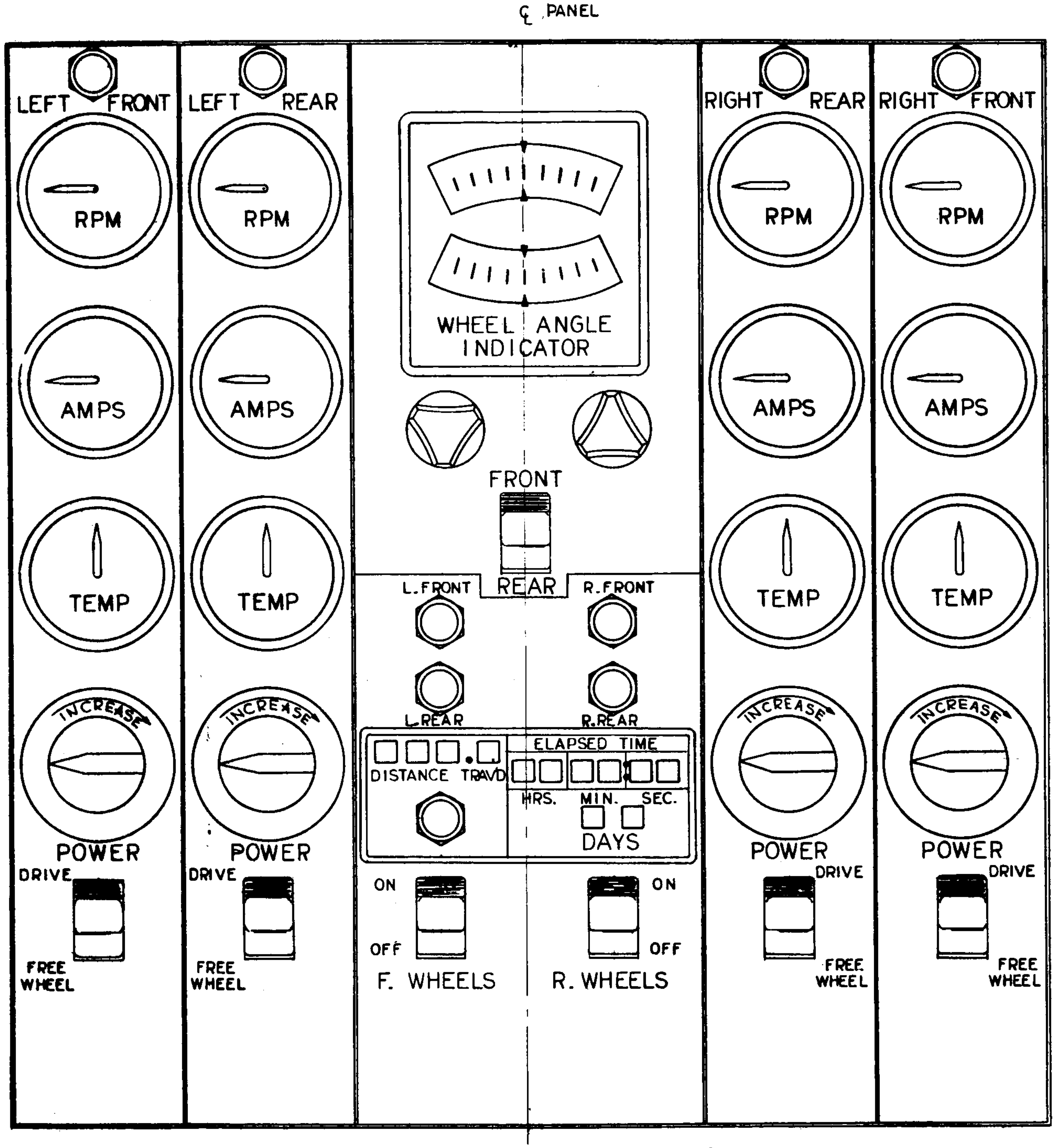

CONTROL HANDLE (SHOWN AT APPROX. 5 MPH POSITION)
FORWARD
REVERSE
NEUTRAL (& DYNAMIC BRAKING)
SLOT IN CONTROL CONSOLE SURFACE
PLAN
FULL SPEED 10 MPH
FORWARD RANGE 10 NOTCHES @ 1 MPH/NOTCH
1 MPH
NEUTRAL
NEUTRAL
REVERSE RANGE 5 NOTCHES @ 1 MPH/NOTCH
½ MPH
2½ MPH FULL SPEED
PLAN
DETENT ARRANGEMENT
CONTROL LEVER
EMERGENCY STOP CONTROL. ALL LOCOMOTION SYSTEMS OFF - PUSH TO RESET - BUTTON FLUSH WITH TOP OF CONTROL CONSOLE
LOCATION NOT DEFINED
RAISED RING TO PROTECT AGAINST ACCIDENTALLY PRESSING BUTTON
CONTROL CONSOLE
FRONT OF CONSOLE
TRAVEL REQUIRED TO MAKE CONTACT FOR SIGNAL TO TURN-MOTORS (LEFT TURN SHOWN)
15°
FLEXIBLE BOOT AROUND PIVOT POINT
SPRING-WOUND HINGE TO HOLD HANDLE IN VERTICAL POSITION - REQUIRES PRESSURE TO TILT TO TURN POSITION
MOMENTARY CONTACT POINTS FOR TURNING
KNURLED HANDLE
BASE SUPPORT FOR HEEL OF HAND
UPPER SURFACE OF CONTROL CONSOLE
SPRING-LOADED DETENT PIN
SHAFT TO CONTROL MASTER BOX
DETENT PANEL
WIRES FROM TURNING CONTACTS TO CONTROL MASTER BOX
END VIEW
NOT CONCEPTUAL SHAPE
SHAPE OF HANDLE TO CONFORM TO ANTHROPOMETRIC STUDIES OF MANIPULABILITY OF 5TH TO 95TH PERCENTILE GLOVED HAND (USAF PERSONNEL)
SIDE VIEW
CONCEPT OF MECHANISM: TO INCORPORATE ALL FACETS OF MOBILITY CONTROL
CONCEPT DESIGN
MOLAB
MULTI-FUNCTIONAL
CONTROL LEVER
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA
REVISIONS
APPLICATION
D
FULL

FIG 1



CONCEPTUAL DESIGN OF
LOCOMOTION CONTROL PANEL
FOR A MOLAB

FIG. 2

DISTRIBUTION

INTERNAL

DIR
DEP-T
R-AERO-DIR
 -S
 -SP (23)
R-ASTR-DIR
 -A (13)
R-P&VE-DIR
 -A
 -AB (5)
 -AL (5)
R-RP-DIR
 -J (5)
R-FP-DIR
R-FP (2)
R-QUAL-DIR
 -J (3)
R-COMP-DIR
R-ME-DIR
 -X
R-TEST-DIR
I-DIR
MS-IP
MS-IPL (8)

EXTERNAL

NASA Headquarters
 MTF Col. T. Evans
 MTF Maj. E. Andrews (2)
 MTF Mr. D. Beattie
 R-1 Dr. James B. Edson

Kennedy Space Center
 K-DF Mr. von Tiesenhausen

Hayes International Corp.(5)
Apollo Logistic Support Group
Huntsville, Alabama

Scientific and Technical Information Facility
P.O. Box 5700
Bethesda, Maryland
 Attn: NASA Representative (S-AK/RKT) (2)

Manned Spacecraft Center
Houston, Texas
 Mr. Gillespi, MTG
 Miss M. A. Sullivan, RNR
 John M. Eggleston

Donald Ellston
Manned Lunar Exploration Investigation
Astrogeological Branch
USGS
Flagstaff, Arizona